New means of communication

Universal communication systems that have the flexibility and modalities of the human nervous system—with which men could, at will, talk, hear, see, gesticulate, write, examine documents, and even manipulate machines—are coming within reach. All we need to do is foresee what is really wanted or needed, a major problem in itself

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In the past, men viewed different modes of communication, such as telegraphy and telephony, as being fundamentally different in kind, a view that has been dispelled by technological advances and especially by the communications theory of Shannon. The way is now open to achieve a universality in electrical communications systems analogous to that of the human nervous system in which different sensory functions—vision, hearing, taste, etc.—are served by uniform nervous transmission lines that differ only in the different types of sensory transducers in which they terminate. There are technical problems and challenges in achieving a future universal communication system that will serve all man's needs, but there are also other obstacles rooted in obsolete social and legal concepts.

I want to begin by observing an interesting contrast between man's internal communication system and the electrical communication systems that serve him. Over the years, neurophysiologists have learned a good deal about the nervous system. They have found that nerves are the same, whatever sense they serve. Electric impulses travel along nerves, and are chemically regenerated as they travel. Sometimes there are pulses in the absence of a stimulus, sometimes only during the stimulus. But the pulses themselves are the same, whether we are listening, smelling, or hearing. Indeed, the same sort of nerve impulses are used in controlling our muscles.

The difference between the various modalities of communication or sense within the human being are merely differences in the types of transducers at one end of the nerve. Certain nerves are sensitive to touch, others to heat, others to light or to vibration, but all generate the same sort of nerve impulses. We do not understand why we have different sensations—of sight, of sound, of smell—but clearly this must be related to the fact that the nerves associated with different senses are connected to different receiving mechanisms, different sensory transducers.

Thus, in all the varied forms of communication that we use—speaking, seeing, gesturing, and so on—our internal communication signals are carried in the same way, and we see a difference in purpose, if you wish, only in transducers and receptors.

Finding unity amidst diversity

We can find a unity among different methods of electrical communication by recognizing that the different methods all use electric currents. However, in the early days of electrical communication we did not see this unifying principle. Instead, we were acutely conscious of special inventions of a rather primitive kind.

Samuel F. B. Morse invented a form of the telegraph that made use of off–on signals and the very ingenious Morse code. The signal from the key was effective over medium distances; to send the signal further, you provided relays at intermediate points. These relays would respond only to off–on signals. At the far end of the telegraph circuit, a sounder made a sound.

This was not, however, the whole of the communication system that was then known as telegraphy. There was also the messenger boy. At the sending end we had to write out the message, and at the receiving end the messenger boy had to take it to someone's home.

At one time, telegraph service of this type was an almost universal form of communication; it could reach from a telegraph office to almost any home in the country. Indeed, business offices were provided with electric signaling devices for summoning telegraph messenger boys so that businessmen need not go to a telegraph office to send a message.

When Alexander Graham Bell invented the telephone, it seemed very different from the telegraph. The messenger boy, who had been an integral part of telegraphy, was eliminated. Telegraphy would have meant nothing without the human link at the ends, for the message would not have reached anybody. However, the telephone was on the premises at both ends, and the telephone circuit was not just a circuit extended between two offices. Through switching, the telephone enabled one to communicate directly with any one of a number of people. Another difference between the two systems was that the telephone signal did not travel over a telegraph circuit equipped with relays.

You will notice that I had to retrogress many years to make telegraphy and telephony look different. As electrical communication developed, it was found possible to send telegraph signals over telephone lines. In fact, today telegraph and teletypewriter signals are carried over the same communication facilities that send voice. A small part of the bandwidth is allocated below the voice channel, or else the voice channel is filled with "carrier signals" of different frequencies, which enables many telegraph signals to be sent over one circuit. The contrary is also true. In pulse code modulation, which is now in commercial service, one reads the successive amplitudes of a continuously varying signal, and represents these by numbers, which in turn are represented by strings of binary, off–on impulses. In pulse code modulation the signal is not a continuous signal, but is discrete, limited to certain amplitudes sent periodically at predetermined times. This is certainly reminiscent of telegraphy.

The communication plant that has evolved in the telephone system, and which carries telegraph messages (or data, or teletypewriter), has not achieved the degree of uniformity that we find in the nervous system, where everything is sent as pulses. It has, however, achieved the uniformity of function. If you pick up your telephone or use a teletypewriter, you have no way of knowing how the signal is being transmitted. It may be transmitted by the on–off pulses of pulse code modulation, or by a baseband signal translated in frequency and sent via coaxial cable or via a microwave radio relay.

The electronic art has become so flexible that we can achieve the same overall effect from terminal to terminal with any of the circuits in existence. Furthermore, we can predict that future circuits will accommodate any signals we may wish to send.

Telegraph service as we once knew it is a thing of the past. The messenger boy is gone (probably working as a communications engineer by this time). What we now think of as telegraphy involves telephoning a message to the telegraph office.

Communication theory

We have at last achieved in electrical communication something that in effect is very much like the universality of communication within the human being. Different aspects of communication are served by communication circuits, and the purpose being served depends on the terminal equipment at the ends of the circuits, not on the circuits themselves.

This has all been formalized mathematically in Shannon's communication theory. Shannon defines a common unit of information that is equally applicable to voice signals, facsimile signals, television signals, or data signals. That measure or *bit* information is a binary choice, a yes or no. Shannon defines a *capacity* of communication circuits, likewise universal, and not dependent upon the modality of communication. This measure is the channel capacity of the circuit, measured in bits per second.

Shannon points out that we have in communication a source generating information at a certain rate that can in principle be deduced by examining the signal which the source generates. We can describe the capacity of circuits to transmit such signals in bits per second. This makes it much easier to talk about the present state of communication and the new possibilities of communication than it would be were we living in the day of primitive inventions when each system was viewed as a distinct and different type.

Today, from every place of business, from almost every home, there extend electric circuits that can be set up through the telephone plant. Various transducers can be connected at each end. It is the character of these transducers that determines the particular aspect of the human need for communication the circuits will serve. This, then, is closely analogous to human internal communication, in which we have nerve endings sensitive to sight, sound, touch, taste, and so forth, but a common transmission medium that serves all messages. Today, to the same communication network you can connect a keyboard, a typewriter, a telephone instrument, or a television device.

Let us consider such communication circuits. How much channel capacity must they provide for various sorts of communication? Telegraphy, for example, takes little channel capacity, voice takes a little more, fast data take a lot more, and television takes a great deal more. In meeting communication needs there are two problems. The first is that of expanding the capability of the already universal network that makes use of coaxial cables, pairs of wires, microwave radio relays, submarine cables, and satellites. The second has to do with providing transducers that will enhance the human process of communication through sight, sound, and, perhaps ultimately, touch and smell.

New communication systems

What can we see in the future? This broad universal commodity—electrical communication—is useful chiefly because it *is* universal; because it will connect anything with anything else. A new communication circuit would be of little use if only a few people could use it or if it could be used only in a restricted area. Not everyone need have a new form of communication at first, but it is essential that it be universally available, that it extend, say, from New York to Los Angeles.

Here we must confront the problem of channel capacity. How can we expand the channel capacity to provide more communication—faster and cheaper? We must disregard particular human uses of communication channels, because that is not relevant. All sorts of communication must go over the same circuits.

There are many promising new approaches to more economical communication. First, there is the extension and improvement of things we already have, through advances such as the transistor and, more recently, through the revolution of microelectronics. Components too costly yesterday are not costly now and will be cheaper tomorrow. Obvious examples are the pocket radio, alerting devices, and improved radio receivers in automobiles. Another example is a communication system called the T-1, that transmits some 1½ million plus or minus pulses per second over a pair of wires that might otherwise carry one voice conversation. Transistors have doubled the communication capacity of a coaxial cable with respect to what could be attained with vacuum-tube amplifiers.

The transistor is also bringing us microwave systems that are simpler and cheaper than those of the past. The first microwave systems were extremely expensive. They had huge standby power plants, and repeaters were located on expensive hilltop sites about 30 miles apart. Now you can make a microwave repeater that is self-contained. The standby power is a couple of storage batteries. You do not need expensive equipment or sites. You can use such systems on all kinds of routes, all over the country.

Further developments will make communications by microwaves even cheaper and more flexible. Beyond this, however, there is a problem of transmitting very broadband signals, such as those associated with television, across the continent. We know that the art is available for sending millimeter waves through pipes or waveguides between amplifiers perhaps 15 miles apart. One pipe could be used to transmit 100 000 two-way telephone channels or 200 channels of television bandwidth.

Such a waveguide system could come into being when there is an economic need for it. Technically it is already feasible, but it is not clear whether so much communication capacity is needed. Beyond millimeter waves we have coherent light, a truly new thing under the sun. Coherent light from lasers has inconceivable bandwidth. We know how to guide it through pipes with gaseous lenses. The art is not enough advanced to build a useful system, but a practical resource can be created through further work. Thus, by utilizing future developments, we can find ways to expand our electrical communication to meet future needs.

The unforeseen needs

I am sure that in the future there will be needs that we cannot foresee—but there will also be ways that we cannot foresee for providing more communication. Progress is a matter of working hard, and then recogniz-

ing the right time when economic conditions call for new things.

Some years ago it seemed to us that it would be very expensive to bridge the oceans with broadband communication so that we could communicate as readily across the world as we can across the continent. Today we have broadband submarine cables; and transistorized cables will have a capacity of an order of magnitude greater than the first vacuum-tube cables. We also have communication satellites. These are another piece of a complicated network that can send any signal to a far point over many media—partly over a pair of wires, a coaxial cable, microwave radio, and communication satellite. At the ends of the circuit you cannot tell what sort of circuit is being used.

The challenge of broader band and more economical communication circuits is a great challenge, but it is one I think will be met. There is another great challenge. That is to adapt this marvelous communication network to the needs of man—needs that can be foreseen, and needs that cannot. Needs are not necessarily something that exists independently of means. They come into being and grow. There was no need for the telephone before the invention of a telephone. People got along very well without it. If the telephone had been destroyed a year after it came into being, no one would have missed it. If it were destroyed now, society would be in chaos. The same can be said about the automobile. Thus, needs come into being and grow as new means come into being. We cannot always foresee needs. Nevertheless, we can see many of them.

Civilization today does not exist merely in a few big cities. It extends over the face of the country and over the face of the globe. In doing the world's work, people continually fly from the West Coast to the East Coast just to converse with one another for a short time. This is wasteful. The happy future would be one in which we could use electrical communication with something approaching face-to-face flexibility—a world in which we would not choose among modes of communication but would use them all. The communication system we need would enable us to talk, to hear, to see, to gesticulate, to write, to examine documents, and even to manipulate machines.

Why should you have to go to a bank or call a bank to tell somebody to do something to your account? Why should you have to call somebody in a department store to tell him your selection, whereupon he must enter it into the books and charge it to you? This human link seems as unnecessary as the telegraph messenger boy. Obviating this link, too, is a great challenge.

The challenge is partly technological, but it is also partly that we do not yet understand human beings as well as we need to. What things should come first? What things are most important? In a conference, for instance, you do not want everyone holding a telephone in his hand—or is this true? You would probably like distant talking devices. But this desire raises technological problems because of feedback from the loudspeaker to the microphone. This problem can be tackled in a number of ways, all of which have limitations. Furthermore, in a conference between two groups of people, how do you know who is talking? Experience indicates that if people know one another very well they can keep the conferees straight because they recognize the voices. If you are in a conference with unfamiliar people you are nevertheless able to see them, and you learn to identify them even before you hear them speak. That factor is missing in conferences via telephone today. Perhaps you need television, but what kind of television do you want? Must it provide sufficient detail so that you can read maps? Or do you want a keyboard along with your conference? Or do you want a telewriting machine? These things must be tried out. I do not think you can guess what will be needed.

Another thing that is missing from today's communications systems is the element of secrecy or security. For classified Washington business, a device is needed at the terminals that will frustrate wiretappers. This can be done, but it may be costly.

It is more difficult to evaluate such options than you might believe. You try a combination and find that some people get along with it. But how much can you generalize? How much is necessary? You provide people with a lot of things; how much can you take away? It is very difficult to judge. In the end, all these services will have to be offered to the public, but it is difficult to know when they should be offered, or in what order. It is certainly possible to have television from home to home, or from office to office, but at present there are obstacles. One is the cost and the reliability of the terminals, although transistors help greatly in reducing terminal cost and increasing reliability. Another obstacle is the cost of the circuits, although advances will make transmission less costly.

I predict a great many advances in improving both circuits and terminals. Probably we will have telewriting and Picturephones, such as were demonstrated at the 1964–65 New York World's Fair. Advances will also make it possible for us to communicate with machines—for instance to give problems to a computer over a telephone. In the future when you need information or service you will be able to call a computer. You will be able to query libraries as well as people.

Nontechnical obstacles

There are obstacles other than the technological obstacles in going toward the future in communications. There are legal obstacles to face. Traditionally, the Federal Communications Commission tends to be interested not in communication but in modalities of communication. Conforming to this pattern, Congress has set up satellite communication as a particular technique that is operated independently of common carriers although it ties into their circuits in providing a service to users.

Such thinking leads to queer questions such as: "Would you like some improved form of telegraphy, or would you like a telephone?" This is reminiscent of the question: "Would you rather be blind, or would you rather be deaf and dumb?" It seems to me to be an unnatural question. I hope that, in the long run, laws and regulations of communication will leave room for a universality and improvement of communication so that we can all use in our daily affairs all the modes of communication with which technology can economically supply us.

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